DRAFT

Drought and the Sacramento-San Joaquin Delta, 2012-2016: Synthesis Review and Lessons

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"You know when it floods, but when does it drought?"

--attributed to J. G. Boswell

"Planning is more important than plans."

--anonymous

Executive Summary

This report reviews the effects of the 2012-2016 drought on the Sacramento-San Joaquin Delta (Delta) and Sacramento River of California, the actions taken to manage it, and the science used to support and evaluate those actions. Interviews were conducted with managers and stakeholders involved with wildlife and water management to identify main points of interest and using reports and other grey literature as supporting documents. Delta salinity control, water supply, invasive aquatic vegetation, Delta smelt declines, high river temperatures for winter-run Chinook salmon, and Chinook hatchery management and outmigrant mortality were studied as examples of key challenges for Delta managers. Key Lessons are derived from these studies, and are followed by Recommendations to prepare for future droughts and climate change.

The drought tested the ability of California's water system, managers, and users to adapt to water scarcity and high temperatures. Successes, failures, and points of conflict arose, revealing the system's strengths and weaknesses. Reduced water allocations for environmental and economic purposes, careful stewardship of water supplies, and tactical use of infrastructure, allowed some control of salinity in the Sacramento San Joaquin Delta. Predictable, but diminished, water deliveries were maintained even during the most extreme years of drought. Local and regional water supply portfolios and conservation initiatives provided some flexibility for urban and agricultural water managers. However, one more year of drought would have likely resulted in a saltier Delta with greater consequences for agriculture and economy.

Flows for endangered species protections were portrayed in political rhetoric as consuming an inordinate amount of water; however, relatively small allocations were made exclusively for native species. Most managed flow releases were used to maintain water quality for in-Delta agricultural and municipal water uses. These flows may have provided incidental aquatic ecosystem benefits for fishes. High temperatures, nutrient loads, and low flows may have facilitated an expansion of invasive aquatic vegetation that will be difficult to reverse. Increases in salinity were insufficient to inhibit growth.

Sacramento River temperatures below Keswick Reservoir could not be controlled, leading to near extinction of wild juvenile winter-run Chinook in 2014 and 2015. A third year with similar warm-water conditions would have wiped out most of the wild population, leaving only a captive broodstock. High summer water temperatures in the Delta were difficult to address with short-term responses because they require long-term planning to mitigate.

The record-setting precipitation of the water year 2017 shifted attention to flood management and away from the difficulties of drought. However, drought impacts will persist for many years, even when followed by above average precipitation, because groundwater storage, soils, and plant and animal populations need time and favorable conditions to recover. The drought of 2012-2016 is part of an ongoing recent trend toward warmer and drier conditions. Although this drought broke historical records for diminished snowpack, high temperatures, and low overall precipitation, both California's long-term climate record and climate predictions suggest more frequent and extreme droughts in the future.

The difficulty in predicting short-term trends was highlighted by water year 2018, during which total precipitation was governed by just a few large storms, some coming after February. The dry winter season, followed by increased precipitation in March, brought discussion of renewed drought and uncertainty to water planning. In general, the current structure of water rights appropriations, water quality regulations, and flow requirements constrains the ability of management to respond to drought. Infrastructural, ecological, and institutional changes that provide flexibility are needed, such as conveyance interties, off-channel storage, habitat restoration, water market trading, voluntary settlement agreements, robust species stocks, and environmental water allocations. Prioritizing investments in these tools during inter-drought periods will help to create resilience against short-term droughts and long-term climate change.

Key Lessons

All who depend on the Delta for jobs, farms, water, or recreation have an interest in successful management of the Delta's diverse problems, including the challenges of drought and climate change. This section examines drought management actions that had clear environmental outcomes, and opportunities to improve response.

1. **Drought preparations and actions were slow to begin until the official drought declaration.** State and Federal employees were largely unable to act until after the Governor's drought emergency order, even though drought impacts were apparent. This exacerbated negative outcomes. Managers should have a pathway for responding proportionally to threats as they emerge. Given wide variation in annual precipitation patterns and limitations in forecasting, it may be reasonable to approach every year as a drought year until determined otherwise.

2. **Interagency communication, trust, and transparency affect outcomes.** The Real-Time Drought Operations Team (RTDOT) process greatly improved interagency communications and rapport during the drought, especially at higher levels of management. Despite these gains, a lack of trust between agencies sometimes inhibited data- and information-sharing, preventing operations managers from making decisions with the best possible knowledge. Differing mandates and goals also interfered with concerted action, driven by the conflict between water supplies for people and fish. For scientific analysis to support actions for the public interest, there must be transparency in data, analysis, results, and policy determinations.

3. **Agencies lacked staff and funding to take advantage of the drought scientifically.** In general, agencies lacked resources to meet the increased technical, operational, and scientific demands imposed by the drought. While the executive order galvanized management response and released additional funding, cumbersome hiring practices, limited candidate pools with required technical skills, and limited capacity to rapidly train new personnel thwarted implementation of drought studies. As a result, agencies were not prepared to assess effects of extreme conditions under drought, or provide needed information in real-time.

4. **Interruptions in funding for science and long-term monitoring jeopardized successful management**. Periodic cuts to scientific programs forced a contraction of monitoring, and caused maintenance of vital equipment to lapse. With the end of the emergency drought declaration, funding for some programs ceased. Interruptions undermined long-term data sets and the ability of real-time monitoring to support crisis-based decision making.

5. **A salinity barrier was effective but needs further post-implementation analysis.** The False River Salinity Barrier helped stabilize water quality for export and in-Delta use. The barrier was monitored for effects on water quality, zooplankton and local hydrodynamics while in place, but uncertainties remain about the volume of water “saved” and the utility for salinity management in the south Delta.

6. **The Delta economy showed resilience to most drought-imposed costs.** Compared to other areas of the state, the quantitative economic impacts of drought in the Delta were relatively small; however, qualitative impacts highlight the challenges of providing a reliable water supply for California while protecting Delta place values. Urban water users adapted to supply limitations but with the

consequence of increased rates. Agricultural impacts included reduced applied water under voluntary agreements and fallowing of some land in 2015. Slight but chronic salinity increases in irrigation water have the potential to degrade soil quality over the long-term, with implications for agricultural productivity and cropping decisions. In-Delta service providers and recreational users suggested declines in recreational opportunities and place-based values.

7. **The Delta ecosystem was poorly managed during drought.** Slow moving, warm water conditions expanded, favoring invasive non-native aquatic species, including plants. Processes and animals requiring cold water and freshwater flows suffered. Waterfowl were vulnerable to reduction in food resources and fallowing decisions.

8. **Native fishes, with few exceptions, have declined over the past 30 years and entered the drought with depleted stocks.** Vulnerable populations were not allowed to recover sufficiently during inter-drought periods, when water is managed for deliveries, replenishing aquifers, and filling reservoirs. Robust populations have more resilience to stressors, and more potential for recovery, than depleted populations.

9. **Temperature management will likely extirpate winter-run Chinook salmon unless changes are made.** Because winter-run Chinook salmon are limited to one spawning site below Shasta and Keswick Dam, they relied entirely on management of the cold water pool in the reservoirs during drought. However, temperature management was difficult, and the standards inconsistent with fish physiological requirements. National Marine Fisheries Service, as the regulating agency, relied upon USBR, the regulatee, for technical analyses (modeling, monitoring, reporting and forecasting) to inform regulatory decisions, creating an inherent conflict.

10. **Trucking salmon had implicit trade-offs between commercial fisheries and genetic integrity of wild stocks.** Trucking of Chinook salmon juveniles for release in the lower estuary improved survival and supported the commercial fishery, but increased stray rates of the first returning cohort in 2017. These strayed to streams throughout the San Francisco Bay-Delta, increasing some runs (e.g. Putah Creek), but likely causing interbreeding between hatchery and wild fish stocks.

Recommendations

The best near-term solutions to improving drought response is to improve understanding of regulated and structural rigidities in the system. These can be implemented in short order using existing authorities and funding mechanisms and can help prepare for the next drought. Many improvements are already in place from the 2012-16 drought; they should be maintained and cultivated.

More challenging solutions will involve improving the approach to Delta science and drought, which is currently scattershot, without a long-term source of guaranteed funding and without a mechanisms of authority or oversight. Still, with effort, an integrated science program to support Delta management could be implemented within the decade, and would provide deeper understanding of the Delta system and recommendations for improving flexibility, restoration and water management.

The most difficult solutions involve a re-examination of water rights, including dedicated ecosystem water. An environmental water budget would support ecosystem-based management, accountability for wildlife managers and advocates, and could be used flexibly to support habitat restoration and stock rebuilding of native fishes. Other entities have been successful, to varying degrees, at developing this approach, including Colorado, Australia and Spain. In some cases, the solutions required 30 years of negotiation. If this approach were begun now, it would be too late for some species, but not too late to deal with some of the most egregious results of climate change, which will continue to develop for well over the next 100 years.

With this in mind, we recommend the following, in order of increasing difficulty of implementation.

1. **Develop a Delta Drought Plan.** Like floods and earthquakes, droughts can be anticipated, and planning will support rapid and effective response. Such a plan should include:
    a. Establishment of criteria for a Delta drought declaration
    b. Establishment of drought governance
    c. A review of major lessons from past droughts, including analysis of data to understand how wildlife, agriculture, recreation and municipalities were affected
    d. A drought plan for each environmental agency and a coordinated interagency plan
    e. Mechanisms for interagency communication at multiple levels of staffing
    f. Responsibilities and plans for agencies to redeploy resources from drought onset, including funding and flexible staffing strategies

g. Implementation plans for scientific studies to measure drought impacts from onset
h. Advance planning for salinity or other flow barriers, including post-installation analysis
i. A water rights implementation plan, including Project curtailments and voluntary settlement agreements for drought years, with provisions for compensation of losses to privileged water rights users

2. **Increase functional transparency.** For every program and action, it is important to know who is responsible, and what outcomes resulted. Data and modeling predictions should be freely available among agencies and the public, as well as trainings in how to use the data correctly.

3. **Capture and retain institutional knowledge.** The loss of institutional knowledge due to a surge of post-drought retirements by senior managers may compromise future drought management in California. Efforts are needed to ensure that lessons from previous droughts are recorded and made available to new managers, policy-makers, and the public. A coherent narrative of drought actions and responses should be documented and supported by archived reports and grey literature.

4. **Organize regular "dry runs", or drought drills.** Just as we prepare for floods, earthquakes, fires and other disasters, it is important to refresh and train staff in drought preparedness. Trainings should be cross-agency and focus on historical events and situational "games", using computer modeling, to run through scenarios and vet the outcomes of decision-making. Such "dry runs" should support the Delta Drought Plan to help improve institutional communications, decision-making, and other problems identified in this report.

5. **Improve communications among agencies responsible for Winter-run Chinook salmon survival.** Consensus is needed on the causes of the loss of temperature control on the Sacramento River below Keswick Dam in 2014 and 2015. Future decisions on Shasta's cold water pool and water temperature delivery requirements for winter-run Chinook should be transparent, better supported, and made with consensus from co-trained representatives of SWRCB, USBR, DWR, NMFS and CDFW. Conflicting mandates should be identified and contained to provide objectivity and restore public confidence.

6. **Increase flexibility of operations for ecosystem managers.** The ability of ecosystem managers to respond to drought was limited by a lack of personnel and resources, making it difficult to rapidly

ramp up scientific studies, interventions, and neglected monitoring operations. Interagency communication foundered because of workloads. A Delta Drought Plan is needed that allows ecosystem managers to take rapid actions in response to drought conditions.

7. **Improve and expand scientific work in key areas.** Science needs to be better prepared for the general variability and intermittency of the Delta's hydrology and ecosystem. Droughts and floods offer extreme conditions that help us better understand the Delta's ecosystem, use, and management. These natural experiments would be otherwise impossible to conduct in terms of permitting, costs, and expense. The next drought will provide research opportunities in several areas:
    a. Aquatic vegetation expansion and control
    b. Fish community dynamics, including relationships among native and non-native species and interactions between native fishes and their environment during drought
    c. Calibration of hydrodynamic models to extremes using drought field data; incorporation of barrier function; improvement of Clifton Court operations modeling
    d. Effect of changes in water quality and soil salinity on agriculture and wildlife
    e. Comparisons of water flows, water quality, and biology with existing long-term data sets
    f. Harmful algal bloom formation and dispersal
    g. Institutional, business, recreational and public responses to drought and extreme conditions.

8. **Secure funding streams so continuous monitoring remains in place.** Given the value of the Delta ecosystem, a reliable array of programs must be in place before the next drought, with financial and institutional support, to reduce errors in drought management and improve drought preparation.

9. **Build system reliability (including environment and science) during inter-drought periods.** Active management during inter-drought periods is required to buffer undesirable outcomes during drought. Long-term funding for management and science are required to manage the ecosystem intensively, both during drought and for recovery during inter-drought periods. A scientific program with continuity is needed to help rebuild ecosystem resilience.

10. **Rebuild vulnerable fish stocks between droughts.** The ESA has proven useful for protecting species on the brink of extinction, but not at rebuilding stocks before they become imperiled. Standards to

rebuild fish stocks need to be put in place as part of a larger ecosystem-based management approach, especially when populations become too small to effectively monitor, as they have with Delta smelt.

11. **Allocate ecosystem water with senior rights.** Much of the rigidity of current species-based ecosystem management is due to the lack of a dedicated water right. A water right allows innovative and adaptive approaches to both species and water management, provides accountability for actions' success, provides an end to legal challenges to agency mandates, and offers flexibility to use water directly or sell on the market, providing a portfolio of resources with which to rebuild ecosystems and imperiled fish populations.